Welfare analysis of patent pool using two-good bundling model with multi-dimensional user types: A case of uniform distribution*

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Abstract

Recently, patent pools have been often established by the patent holders in order to promote R&D and set technical standards. Patent pools are one of the administration methods for licensing, that many patent holders concentrate their own patents and the administrator of patent pools offers the package licenses to licensees. This paper discusses the social welfare implications for the patent pool from the view of anti-competitive effect. We consider the asymmetry patents such as the basic patents and optional patents, and investigate whether the patent pool should include optional patents with basic patents. We also examine the two licensing schemes of the patent pools; the single package licensing inclusive of all patents in the patent pool and the multiple packages licensing which is desired by licensees.

Keywords: Basic and Optional Patents, Multiple packages licensing, Patent pools
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1. Introduction

In this paper, we discuss the social welfare implications for patent pools where patent holders concentrate their own patents for commercializing new innovations or for setting standards and the licensing administrator of patent pools offer the package license inclusive of the patents. Recently, it has been serious problem that many firms can not develop new technology and new products by using only their own patents, because of the advancement of technologies and the segmentation of research fields. In order to commercialize new technology and new products, firms have to negotiate the licenses with many patent holders, who are scattered in various research fields. These negotiations bring about the various costs such as the transaction cost and the seeking-technologies cost. A patent pool is expected as the useful means to solve those problems. It is pointed out that a patent pool enables firms to reduce the transaction costs and the seeking-technologies cost by simplifying the license contract and, furthermore, to avoid patent litigation and to establish technical standardization such as MPEG-2, DVD, and 3G. [1]

However, there is the possibility that a patent pool can exercise monopoly power as a major cartel, since a patent pool constitutes cooperative activity between patent holders. Historically, patent pools have been abused since the early 1900s.[2] Priest (1977) indicated that a patent pool has the incentive to disguise cartel by using cross-license, since the patent law gives the patent holder strong right which includes the output, the allocation of territories, the fixed lowest price, etc. Thus, the antitrust enforcement of many countries is characterized by a deep-rooted suspicion of a patent pool. Our concern is determining whether patent pools are pro-competitive or anti-competitive.

The U.S. antitrust enforcement focuses primarily on the technical relationships among the patents included in patent pools.[3] According to its view, patent pools do not pose any antitrust problems when "*essential*" patents are included in patent pools to achieve the purpose of the pools, for example, technical standard and settlement of patent litigation, etc. Although U.S. guideline does not explicitly state the technical relationships among the patents included in the pool, the U.S. antitrust enforcement agreed to patent pools, which include the minimum patents to achieve the purpose of the pools, on past business review letters.[4] European Commission also agrees to patent pools to which the U.S. antitrust enforcement agrees.[5]

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[1] "Patent pool" has two patterns as the administration of methods for licensing. The first scheme is that patent holders grant the rights of their sublicenses to the licensing administrator of patent pools, and the licensing administrator offers to licensees. The second scheme is that patent holders do not grant the right of sublicenses to the licensing administrator, and patent holders directly offer the licenses to licensees through the licensing administrator as the agency.

[2] See Klein (1997) and Gilbert (2004) for historical perspectives on the anti-trust treatment of patent pools.

[3] The Department of Justice focused on the technical relationship among the pools in three business review letters regarding an MPEG patent pool and two DVD patent pools. See Shapiro (2001) for details.

[4] See Business Review Letter MPEG-2 II. A

[5] See Guidelines on the application of Article 81 of the EC Treaty to technology transfer agreements (2004/C 101/02).

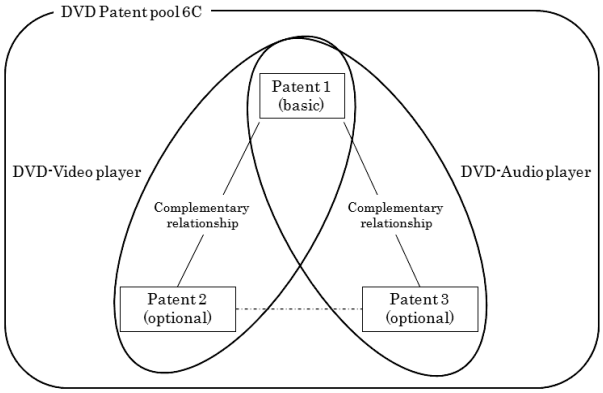
Shapiro (2001) and Lerner and Tirole (2004) provide the theoretical background for the view of the U.S antitrust enforcement and European Commission. Those literatures focus on the technical relationships among the patents included in the pool, and investigate whether patent pools have an anti-competitive effect. In Shapiro (2001), all the patents in the pool are complementary, i.e. licensees cannot get gross surplus, even if just one patent lacks in the patent pool. Shapiro (2001) obtains the explicit result that patent pools are pro-competitive when all the patents in the pool are complementary. Because licensees can place the highest price to maximize their profits under the complementary relationship among patents, the price of patent package in the pool is lower than in the absence of patent pools.

Lerner and Tirole (2004) investigate the case in which they consider substitute relationship among the patents in the pool, in addition to the discussion of the complementary relationship among patents. In Lerner and Tirole (2004), patents are technical substitute when an additional gross surplus of licensees for an additional patent is small. They obtain the explicit result that patent pools are anti-competitive when patents are technical substitute in the pool. These results are consistent with the current U.S. policies and the European policies when the patents of the complementary relationship are interpreted as essential patents.

These literatures assume that patents are symmetry for the simplification of analysis. The assumption of symmetry patents implies that the gross surplus of licensees depends only on the number of patents but not on the combination of patents, so that the analysis is easy by focusing on only the number of patents. However, the assumption of symmetry patents sacrifices the description of the various technology structures in the patent pool. This paper considers two asymmetry technologies; the basic patents and the optional patents. The basic patents are inevitable to develop the products. The optional patents characterize the products by embodying the basic patent. It is important to distinguish the basic patents and the optional patents.

For example, DVD6C patent pool includes basic patents and optional patents. Fig.1 shows the simple structure of patents in DVD6C patent pool. Patent Group 1 is basic technology which is inevitable to produce DVD-Video player or DVD-Audio player. These patents are the basic technologies which extract data from DVD Disc. Patent Group 2 and Patent Group 3 are optional technologies. Patent Group 2 is used to produce DVD-Video player with Patent Group 1. Patent Group 3 is used to produce DVD-Audio player with Patent Group 1. Patent Group 1 has the complementary relationship with Patent Group 2 and 3, and Patent Group 2 does not have the complementary relationship with Patent Group 3.

Fig.1



Another example is the patent pools related to MPEG which are video and audio encoding standards; MPEG2, MPEG4-Visual, MPEG4-Audio, AVC/H.264 etc. MPEG2 is the simplest patent pool which is composed of only the basic patents in order to standardize video and audio encoding technologies. MPEG4-Visual, MPEG4-Audio, and AVC/H.264 are patent pools which are composed of optional patents in order to improve performance and function of products. The MPEG-associated products are characterized by embodying MPEG2 and other patent pools (MPEG4-Visual, MPEG4-Audio, and AVC/H.264). These patent pools are managed by one licensing administrator, MPEG-LA. Therefore, we can regard MPEG-LA as one patent pool which includes the basic patents and the optional patents in this paper.

Our concern is determining whether patent pools inclusive of the basic patents and the optional patents are pro-competitive. The previous theoretical researches have not ever focused on the structure of patents which compose the patent pool. In this paper, we consider a patent pool which includes asymmetry patents; the basic patent and optional patents. We discuss whether the optional patents should be included in the patent pool from the view of anti-competitive effect, and derive analytical implications for social welfare.

We also consider the multiple packages licensing, as one of the licensing scheme, which are packaged within the subsets of all patents in the pool. In practice, it is observed that 12% of the pools surveyed by Lerner et al. (2003) offer the multiple packages licensing. For example, as mentioned before, DVD6C offers the multiple packages licensing in the category of products related to DVD such as DVD-Video Player, DVD Encoder, DVD Decoder, etc. MPEG-LA also offers the multiple packages licensing, which are composed of the basic patent pool (MPEG2) and optional patent pools (MPEG4-Visual, MPEG4-Audio, and AVC/H.264) in order to improve performance and function of product. The multiple packages licensing are the useful way to avoid “tie-in-sales” by allowing licensees to make their own choice. Moreover, the recent guidelines of the European

Commission encourage patent pools to offer the multiple packages licensing as the useful way to provide licensees with a broader choice. Therefore it is important to derive analytical implications for the multiple packages licensing in this paper.[6]

The paper is organized as follows. Section 2 describes the basic set up in our model. By defining licensees' (users') gross surplus for the technologies, we characterize the basic and optional technologies. In section 3, we consider the patent pool pricing case where the patent pool licenses the three technologies to users, monopolistically. The licensing fees are determined by maximizing the patent pool's profit. The two licensing scheme are also analyzed: single package licensing and multiple packages licensing. The single package licensing is the scheme which the patent pool offers only the single package licensing inclusive of all patents in the pool. The multiple packages licensing is the scheme which the patent pool offers the multiple packages licensing inclusive of the subsets of all the patents in the pool. In section 4, we consider the individual pricing case where each patent holder licenses their own technology individually in absent of patent pool. In section 5, we investigate whether the patent pool has anti-competitive effect or not, by comparing the patent pool pricing case with individual pricing case in the total profit of patent holders, the total surplus of the users, and social welfare. And also we can obtain the implication of the multiple packages licensing for the social welfare. Furthermore, the incentive of patent holders establishing the patent pool is discussed. Section 6 discusses the results derived from the analysis conducted in the paper.

2. The patent technologies and the gross surplus of users

In this section, we describe the basic set-up of our analysis. We characterize the gross surplus of "users" or "licensees," which are essential to conduct further analysis. Suppose that there are three patent technologies, patent 1, 2, and 3 which is owned by patent holder 1, 2, and 3, respectively. Patent 1 is basic technology which is inevitable to produce the product, and the patent 2, 3 are optional technologies which characterize the category of products. Users can produce the product by combining a basic technology and two optional technologies. In our model, we distinguish between patent holders and users as well as literatures. Patent holders do not have the ability to commercialize the patented technology on their own. Patent users cannot produce products until they pay the licensing fees to the patent holders.

Users can obtain the gross surplus for embodying the patent technologies, which is represented by $U(X_1, X_2, X_3; \theta)$. $X_i \in \{0,1\}$ $(i = 1,2,3)$ denotes whether patent i is used to produce a product. If $X_i = 1$, patent i is used. If $X_i = 0$, patent i is not used. $\theta = (a,b)$ represents

[6] Under the assumption of symmetry patents, Azetsu and Yamada (2012) analyzes the choice of two licensing schemes; the single package licensing and the multiple packages licensing. They conclude that the patent pool inclusive of complementary patents does not offer the multiple packages licensing.

type parameters ($0 \le a \le 1, 0 \le b \le 1$). The user are distributed on type space, following uniform distribution function, $F(\theta) = ab$, $(\partial F(\theta) / \partial a \partial b = 1)$. The gross surplus of users depends on not only number of patents but the combination of patents.

Our model specifies the user's gross surplus function as the following function:

$$U(X_1, X_2, X_3; \theta) = \begin{cases} 0 & when\ X_1 = 0 \\ aX_2 + bX_3 & when\ X_1 = 1 \end{cases} \quad (1)$$

When the users can obtain the positive surplus, $U(1,1,0;\theta) = a$, $U(1,0,1;\theta) = b$, $U(1,1,1;\theta) = a + b$. The user's gross surplus is zero when patent 1 (basic technology) is not used, even if patent 2 and 3 (optional technologies) are used. The user's gross surplus is also zero when both patent 2 and 3 is not used, even if patent 1 (basic technology) is used. In order to get the positive gross surplus, the user has to embody patent 1 and 2, patent 1 and 3, or all the patents. The users who are higher a can get higher gross surplus by combine patent 1 and 2. The users who are higher b can get higher gross surplus by combine patent 1 and 3.

3. Patent pool pricing

We assume that the patent pool is established by one basic patent holder and two optional patent holders, and offers the licenses monopolistically. The patent pool offers users package licenses, denoted by $\left(X_1, X_2, X_3;\ P(X_1, X_2, X_3)\right)$ where $X_i = \{0,1\}\ (i = 1,2,3)$. $X_i = 1$ implies that the package license includes the patent i; $X_i = 0$ implies that the package license does not include. $P(X_1, X_2, X_3)$ is the licensing fee of the package license. For example, the package license $\left(1,1,0;\ P(1,1,0)\right)$ implies that the patent 1 and 2 are licensed for licensing fee $P(1,1,1)$.

In this section, we consider two cases: case A where the patent pool offers only the single package license inclusive of all patents in the pool, $\left(1,1,1;\ P(1,1,1)\right)$, and case B where patent pools offer the multiple packages licensing inclusive of the subsets of all the patents in the pool, $\left(1,1,0;\ P(1,1,0)\right)$, $\left(1,0,1;\ P(1,0,1)\right)$, $\left(1,1,1;\ P(1,1,1)\right)$.

The sequence of licensing is as follows. First, the patent pool decides the licensing fees. Next, the users decide which packages to buy. In the following section, we characterize the equilibrium by backward induction.

Case A: single package license

At first, we consider the case where the patent pools offer only the license of the single package inclusive of all patents in the pool with the fee $P(1,1,1)$. Given the package licensing fee $P(1,1,1)$, the users choose whether to buy the package $\left(1,1,1;\ P(1,1,1)\right)$ or not, to maximize their net surplus,

as expressed below:

$$U\left(X_1, X_2, X_3; \theta\right) - P\left(X_1, X_2, X_3\right), \tag{2}$$

where $X_i \in \{0,1\}\ (i = 1,2,3)$ and $U\left(X_1, X_2, X_3; \theta\right)$ is specified by (1). When the user buys the package, the user's surplus is $a + b - P(1,1,1)$, while the user's surplus is zero when the user does not buy. Then, the users who satisfy $a + b - P(1,1,1) \geq 0$ buy the package. The area A^1 in Fig. 2-1 and Fig. 2-2 represent the types of users who buy the single package; Fig. 2-1 when $0 \leq P(1,1,1) \leq 1$, and Fig. 2-2 when $1 \leq P(1,1,1) \leq 2$. Calculating the aggregate demand for the single package,

$$D^S = \begin{cases} \displaystyle\int_0^{P(1,1,1)} \int_{-a+P(1,1,1)}^{1} 1 \; db\, da + \int_{P(1,1,1)}^{1} \int_0^1 1\, db\, da \\ \qquad = 1 - \frac{1}{2}\left\{P(1,1,1)\right\}^2, \quad if\ 0 \leq P(1,1,1) \leq 1. \\ \displaystyle\int_{P(1,1,1)-1}^{1} \int_{-a+P(1,1,1)}^{1} 1\, db\, da = \frac{\left\{2 - P(1,1,1)\right\}^2}{2}, \quad if\ 1 \leq P(1,1,1) \leq 2\ . \end{cases} \tag{3}$$

Fig. 2-1

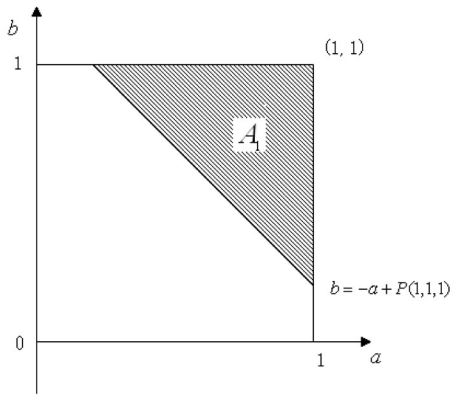
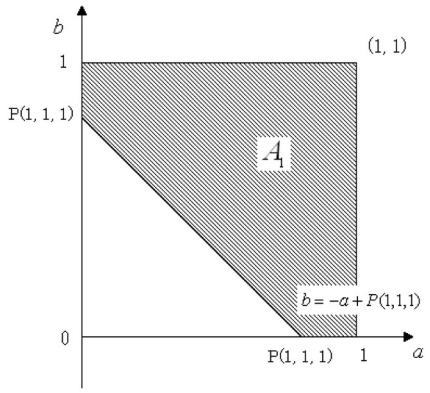


Fig. 2-2



Next, under the aggregate demand function (3), the patent pool decides the licensing fee $P(1,1,1)$ to maximize the following profit:

$$\prod^S = \max P(1,1,1)\, D^S . \tag{4}$$

In the following of the analysis, we ignore the costs paid by the pool members for developing their own technologies, for simplicity. Solving the maximization problem (4), we get the package licensing fee, $P(1,1,1) = \sqrt{2/3} \simeq 0.816$ (See appendix 1). Since we know the licensing fees, we can calculate the total profit of patent holders (patent pool's profit), $\prod^S = 2/3 \simeq 0.667$. The total surplus of users adding up the all of users' net surplus is also calculated as following,

$$US^S = \int_0^{P(1,1,1)} \int_{-a+P(1,1,1)}^{1} (a+b)\, db\, da + \int_{P(1,1,1)}^{1} \int_0^1 (a+b)\, db\, da - P(1,1,1)\, D^S .$$
$$\simeq 0.152 .$$

Furthermore, we can find that the social welfare is $W^S = \Pi^S + US^S \simeq 0.819$.

Result 1. *When the patent pool is established and offers only the single package license* $\left(1,1,1;\ P(1,1,1)\right)$, *the package licensing fee is 0.816. The total profit of patent holders is* $\prod^S \simeq 0.667$, *and the total surplus of users is* $US^S \simeq 0.152$. *Then the social welfare is* $W^S \simeq 0.819$.

Case B: multiple packages licensing.

Given the licensing fees by the patent pool, the users choose the packages of patents, $\left(1,1,0;\ P(1,1,0)\right)$, $\left(1,0,1;\ P(1,0,1)\right)$ and $\left(1,1,1;\ P(1,1,1)\right)$, to maximize their net surplus (2). The choices of user for the patent packages are the following manner:[7]

・The users does not buy any package,

$$\text{if } a - P(1,1,0) < 0,\ b - P(1,0,1) < 0,$$
$$\text{and } a + b - P(1,1,1) < 0. \tag{5}$$

・The users choose the package $(1,1,0,P(1,1,0))$,

$$\text{if } a - P(1,1,0) \geq 0,\ a - P(1,1,0) \geq b - P(1,0,1),$$
$$\text{and } a - P(1,1,0) > a + b - P(1,1,1). \tag{6}$$

・The users choose the package $(1,0,1,P(1,0,1))$,

$$\text{if } b - P(1,0,1) \geq 0,\ b - P(1,0,1) \geq a - P(1,1,0),$$
$$\text{and } b - P(1,0,1) > a + b - P(1,1,1). \tag{7}$$

・The users choose the package $(1,1,1,P(1,1,1))$,

$$\text{if } a + b - P(1,1,1) \geq 0,\ a + b - P(1,1,1) \geq a - P(1,1,0),$$
$$\text{and } a + b - P(1,1,1) \geq b - P(1,0,1). \tag{8}$$

Note that the inequality $P(1,1,1) \leq P(1,1,0) + P(1,0,1)$ is satisfied in the case. If the inequality is not satisfied, that is $P(1,1,1) > P(1,1,0) + P(1,0,1)$, then users who need all patents buy both the packages $(1,1,0,P(1,1,0))$ and $(1,0,1,P(1,0,1))$ rather than the package $(1,1,1,P(1,1,1))$.[8]

From (5)-(8), we can find that each packages is demanded by the following users

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[7] We do not need to consider the package license $(1,0,0;\ P(1,0,0))$, since the users can not get any surplus by using only the patent 1.

[8] In appendix 2, we consider the case where the inequality $P(1,1,1) \leq P(1,1,0) + P(1,0,1)$ is not satisfied. When the patent pool offers the two packages $(1,1,0,P(1,1,0))$ and $(1,0,1,P(1,0,1))$, the patent pool set the licensing fees $P(1,1,0) = P(1,0,1) = 0.5$, and the profit is 0.5.

· The users who does not buy any package satisfy $\begin{cases} a < P(1,1,0) \\ b < P(1,0,1) \\ b < -a + P(1,1,1) \end{cases}$ (9)

· $(1,1,0,P(1,1,0))$ is bought by the users who satisfy $\begin{cases} a > P(1,1,0) \\ b < P(1,1,1) - P(1,1,0) \\ b \le a + \{P(1,0,1) - P(1,1,0)\} \end{cases}$ (10)

· $(1,0,1,P(1,0,1))$ is bought by the users who satisfy $\begin{cases} b > P(1,0,1) \\ a < P(1,1,1) - P(1,0,1) \\ b > a + \{P(1,1,0) - P(1,0,1)\} \end{cases}$ (11)

· $(1,1,1,P(1,1,1))$ is bought by the users who satisfy $\begin{cases} b > P(1,1,1) - P(1,1,0) \\ a > P(1,1,1) - P(1,0,1) \\ b \ge -a + P(1,1,1) \end{cases}$ (12)

Fig. 3

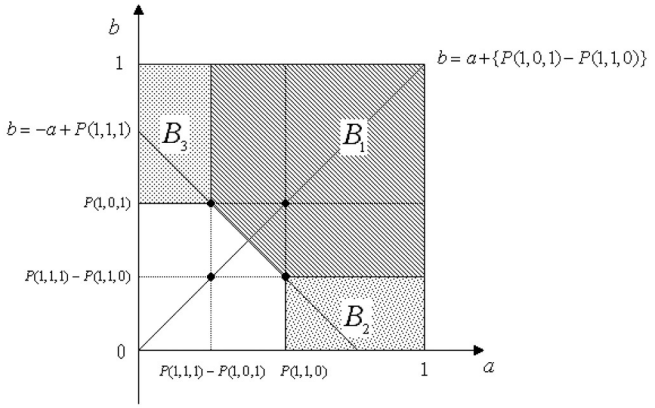


Fig. 3 represents the areas in type space of which users buy each package. B^1 is the area of users who buy the package $(1,1,1,P(1,1,1))$. B^2 and B^3 are the arias of users who buy the package $(1,1,0,P(1,1,0))$ and $(1,0,1,P(1,0,1))$, respectively. Calculating the aggregate demands for each package,

$$
\begin{aligned}
D_{111}^{M} &= \int_{P(1,1,1)-P(1,0,1)}^{P(1,1,0)} \int_{P(1,1,1)-a}^{1} 1 \, db \, da + \int_{P(1,1,0)}^{1} \int_{P(1,1,1)-P(1,1,0)}^{1} 1 \, db \, da \\
&= \frac{1}{2}\Big[P(1,1,0)^2 - \{P(1,1,1) - P(1,0,1)\}^2 \Big] + \\
&\quad \{1 - P(1,1,1)\}\{P(1,1,0) + P(1,0,1) - P(1,1,1)\} + \\
&\quad \{1 - P(1,1,0)\}\{1 - P(1,1,1) + P(1,1,0)\} \ ,
\end{aligned} \tag{13}
$$

$$
D_{110}^{M} = \int_{P(1,1,0)}^{1} \int_{0}^{P(1,1,1)-P(1,1,0)} 1 \, db \, da = (P(1,1,1) - P(1,1,0))(1 - P(1,1,0)) \ , \tag{14}
$$

$$
D_{101}^{M} = \int_{0}^{P(1,1,1)-P(1,0,1)} \int_{P(1,0,1)}^{1} 1 \, db \, da = (P(1,1,1) - P(1,0,1))(1 - P(1,0,1)) \ , \tag{15}
$$

where D_{111}^{M} is the aggregate demand for $\big(1,1,1;\ P(1,1,1)\big)$, D_{110}^{M} is the aggregate demand for $\big(1,1,0;\ P(1,1,0)\big)$, and D_{101}^{M} is the aggregate demand for $\big(1,0,1;\ P(1,0,1)\big)$.

Under the aggregate demand function of (13), (14), (15), the patent pool decides the licensing fees $P(1,1,1)$, $P(1,1,0)$, $P(1,0,1)$ to maximize the following patent pool's profit.

$$
\prod^{M} = \max P(1,1,1) D_{111}^{M} + P(1,1,0) D_{110}^{M} + P(1,0,1) D_{101}^{M} \tag{16}
$$

subjecting to $P(1,1,1) \le P(1,1,0) + P(1,0,1)$ and the licensing fees are not negative. Solving the problem (16), numerically, we can obtain the optimal patent licensing fees, $P(1,1,0) = P(1,0,1) \simeq 0.667$, $P(1,1,1) \simeq 0.862$. From these licensing fees, we can calculate the total profit of patent holders, $\Pi^{M} \simeq 0.550$. The total surplus of users is also calculated as following,

$$
\begin{aligned}
US^{M} &= \int_{P(1,1,1)-P(1,0,1)}^{P(1,1,0)} \int_{P(1,1,1)-a}^{1} (a+b) \, db \, da + \int_{P(1,1,0)}^{1} \int_{P(1,1,1)-P(1,1,0)}^{1} (a+b) \, db \, da \\
&\quad + \int_{P(1,1,0)}^{1} \int_{0}^{P(1,1,1)-P(1,1,0)} a \, db \, da + \int_{0}^{P(1,1,1)-P(1,0,1)} \int_{P(1,0,1)}^{1} b \, db \, da \\
&\quad - P(1,1,1) D_{111}^{M} - P(1,1,0) D_{110}^{M} - P(1,0,1) D_{101}^{M} \simeq 0.254 \, .
\end{aligned}
$$

Then the social welfare is $W^{M} = \Pi^{M} + US^{M} \simeq 0.804$.

Result 2. *When the patent pool is established, and offers multiple packages licensing,* $\big(1,1,0;\ P(1,1,0)\big)$, $\big(1,0,1;\ P(1,0,1)\big)$, *and* $\big(1,1,1;\ P(1,1,1)\big)$, *the package licensing fees are 0.667, 0.667, and 0.862, respectively. The total profit of patent holders is* $\prod^{M} = 0.550$, and the total surplus of users is $US^{M} \simeq 0.254$. *Then the social welfare is* $W^{M} \simeq 0.804$

4. Individual pricing

This section describes the patent pricing which patent holders individually set in absence of the patent pool, and characterizes the pricing behavior of individual patent holders which interacts among the patent holders. Patent holder 1 has technology 1 (basic patent), and patent holder 2 and 3 have the technology 2 and 3 (optional technologies), respectively. Each patent holder decides own licensing fee $p_i \ \ (i=1,2,3)$ at the first stage. In the next stage, the users decide whether or not they should buy each patent. In the following of the section, we characterize the equilibrium by backward induction.

Given the licensing fees $p_1, p_2, p_3,$ the users choose whether or not to buy each patent or not, to maximize their net surplus, as expressed below:

$$U\left(X_1, X_2, X_3; \theta\right) - p_1 X_1 - p_2 X_2 - p_3 X_3, \tag{17}$$

Where $X_i \in \{0,1\} \ (i=1,2,3)$, and $U(X_1, X_2, X_3; \theta)$ is specified by (1). When the user buys patent 1 and 2, user's surplus is $a - p_1 - p_2$. When the user buys patent 1 and 3, user's surplus is $b - p_1 - p_3$. When the user buys patent 1, 2, and 3, user's surplus is $a + b - p_1 - p_2 - p_3$. The behavior of user's purchase for each patent is the following manner;

- The users does not buy any patents

$$\text{if } a - p_1 - p_2 < 0, \ b - p_1 - p_3 < 0, \\ \text{and } a + b - p_1 - p_2 - p_3 < 0. \tag{18}$$

- The users buy patent 1 and 2,

$$\text{if } a - p_1 - p_2 \geq 0, \ a - p_1 - p_2 \geq b - p_1 - p_3, \\ \text{and } a - p_1 - p_2 > a + b - p_1 - p_2 - p_3. \tag{19}$$

- The users buy patent 1 and patent 3,

$$\text{if } b - p_1 - p_3 \geq 0, \ b - p_1 - p_3 \geq a - p_1 - p_2, \\ \text{and } b - p_1 - p_3 > a + b - p_1 - p_2 - p_3. \tag{20}$$

- The users buy patent 1, 2, and 3,

$$\text{if } a + b - p_1 - p_2 - p_3 \geq 0, \ a + b - p_1 - p_2 - p_3 \geq a - p_1 - p_2, \\ \text{and } a + b - p_1 - p_2 - p_3 \geq b - p_1 - p_3. \tag{21}$$

From (18)-(21), we can find that each patent is demanded by the following users;

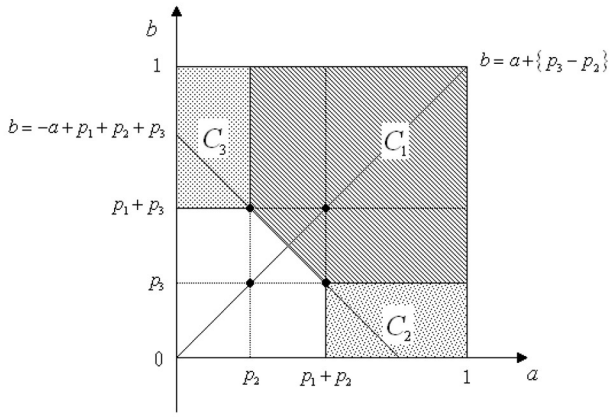
・The users who does not buy any patents satisfy $\begin{cases} a < p_1 + p_2 \\ b < p_1 + p_3 \\ b < -a + p_1 + p_2 + p_3 \end{cases}$ (22)

・Patent 1 and 2 are bought by the users who satisfy $\begin{cases} a \geq p_1 + p_2 \\ a - b \geq p_2 - p_3 \\ b < p_3 \end{cases}$ (23)

・Patent 1 and 3 are bought by the users who satisfy $\begin{cases} b \geq p_1 + p_3 \\ b - a \geq p_3 - p_2 \\ a < p_2 \end{cases}$ (24)

・Patent 1, 2, and 3 are bought by the users who satisfy $\begin{cases} a + b \geq p_1 + p_2 + p_3 \\ b \geq p_3 \\ a \geq p_2 \end{cases}$ (25)

Fig. 4



C^1 in Fig.4 is the area of users who buy all three technologies. C^2 is the area of users who buy the technology 1 and 2. C^3 is the area of users who buy the technology 1 and 3. We can know that The users who buy technology 1 is represented by the area $C^1 + C^2 + C^3$. The users who buy technology 2 is the area $C^1 + C^2$, and the users who buy technology is the area $C^1 + C^3$. Calculating the aggregate demands for each patent,

$$\begin{aligned} d_1^I &= 1-\int_0^{p_2}\int_0^{p_1+p_3} 1\ db\,da-\int_{p_2}^{p_1+p_2}\int_0^{p_1+p_2+p_3-a} 1\ db\,da \\ &= 1-\left\{(p_1+p_2)(p_1+p_3)-\frac{1}{2}p_1^{\,2}\right\} \end{aligned} \tag{26}$$

$$\begin{aligned} d_2^I &= \int_{p_2}^{1}\int_0^{1} 1\ db\,da-\int_{p_2}^{p_1+p_2}\int_0^{p_1+p_2+p_3-a} 1\ db\,da \\ &= (1-p_2)-\frac{1}{2}p_1(p_1+2p_3) \end{aligned} \tag{27}$$

$$\begin{aligned} d_3^I &= \int_0^{1}\int_{p_3}^{1} 1\ db\,da-\int_{p_3}^{p_1+p_3}\int_0^{p_1+p_2+p_3-b} 1\ da\,db \\ &= (1-p_3)-\frac{1}{2}p_1(p_1+2p_2) \end{aligned} \tag{28}$$

where d_1^I, d_2^I, d_3^I are the aggregate demand for patent 1, 2, 3, respectively.

Given other individual patent holder's licensing fees, each patent holder decides the licensing fee to maximize their own profit. Under the aggregate demands (26)-(28), the profits of each patent holder are as follows:

$$\pi_1^I = p_1 d_1 = p_1\left[1-\left\{(p_1+p_2)(p_1+p_3)-\frac{1}{2}p_1^2\right\}\right] \tag{29}$$

$$\pi_2^I = p_2 d_2 = p_2\left[(1-p_2)-\frac{1}{2}p_1(p_1+2p_3)\right] \tag{30}$$

$$\pi_3^I = p_3 d_3 = p_3\left[(1-p_3)-\frac{1}{2}p_1(p_1+2p_2)\right] \tag{31}$$

where π_1^I, π_2^I, π_3^I is the profit of patent holder 1, 2, 3, respectively. Differentiating (29)-(30), we get the following,

$$\frac{\partial \pi_1}{\partial p_1} = \left[1-\left\{(p_1+p_2)(p_1+p_3)-\frac{1}{2}p_1^{\,2}\right\}\right]-p_1(p_1+p_2+p_3)=0 \tag{32}$$

$$\frac{\partial \pi_2}{\partial p_2} = \left\{(1-p_2)-\frac{1}{2}p_1(p_1+2p_3)\right\}-p_2=0 \tag{33}$$

$$\frac{\partial \pi_3}{\partial p_3} = \left\{(1-p_3)-\frac{1}{2}p_1(p_1+2p_2)\right\}-p_3=0 \tag{34}$$

Above three equations of (32)-(33) implicitly represent the reaction functions of each patent holder. The licensing fees in the equilibrium are characterized as the solution of non-linear equations.

Solving these equations numerically, we obtain the solution, $p_1 \simeq 0.400$, $p_2 \simeq 0.383$, $p_3 \simeq 0.383$. The total surplus of users is also calculated as following,

$$US^I = \int_{p_2}^{p_1+p_2} \int_{p_1+p_2+p_3-a}^{1} (a+b)\, db\, da + \int_{p_1+p_2}^{1} \int_{p_3}^{1} (a+b)\, db\, da$$
$$+ \int_{p_1+p_2}^{1} \int_{0}^{p_3} a\, db\, da + \int_{0}^{p_2} \int_{p_1+p_3}^{1} b\, db\, da - p_1 d_1^I - p_2 d_2^I - p_3 d_3^I \simeq 0.111.$$

Then the social welfare is $W^I = \Pi^I + US^I \simeq 0.592$.

Result 3. *When there is no patent pool, each patent holder sets their own patent fee,* $p_1 \simeq 0.400$, $p_2 \simeq 0.383$, $p_3 \simeq 0.383$, *respectively. The spending for using all technology is* $p_1 + p_2 + p_3 \simeq 1.167$. *The spending of users for technology 1 and 3 is* $p_1 + p_2 \simeq 0.783$, *and the spending for technology 1 and 3 is* $p_1 + p_3 \simeq 0.783$. *The patent holders' profits are* $\pi_1 \simeq 0.187$, $\pi_2 \simeq 0.148$, $\pi_3 \simeq 0.148$, *and total profit is* $\Pi^I = \pi_1^I + \pi_2^I + \pi_3^I \simeq 0.483$. *The total surplus of users is* $US^I \simeq 0.111$. *Then the social welfare is* $W^I \simeq 0.592$

5. Welfare implications for a patent pool

In Sections 3 and 4, we characterized the licensing fees in a patent pool and in the absence of a patent pool. We can also obtain the total profit of the patent holders, the total users' surplus and the social welfare. Table 1 summarizes the spending of users for using each patent combination in each case. Table 2 shows the total profit of the patent holders, the total users' surplus and the social welfare. This section discusses the welfare implications for a patent pool, by comparing the case where a patent pool is established with the case where a patent pool is absent. We also discuss the implications for multiple packages licensing.

Table 1

	The necessary spending for using each combination of technologies		
	(1, 1, 1)	(1, 1, 0)	(1, 0, 1)
Single package case	0.817	-	-
Multiple packages case	0.862	0.667	0.667
Individual case	1.167	0.783	0.783

Table 2

	The sum of patent holders' surplus	The sum of users' surplus	Welfare
Single package case	0.667	0.152	0.819
Multiple packages case	0.550	0.254	0.804
Individual case	0.481	0.111	0.592

At first, we investigate whether the patent pool has anti-competitive effect or not, when the patent pool offers only the single package license. We define a patent pool as anti-competitive when the social welfare under a patent pool is lower than that in absent of a patent pool (individual licensing); a patent pool as pro-competitive when the social welfare under a patent pool is higher than that in absent of a patent pool. This comparison is adopted in previous literatures. From table 2, we can find that a patent pool enhances the total profit of patent holders, the total surplus of users and the social welfare from table 2. Therefore the following result is obtained:

Result 4. *If the patent pool is composed of basic patent and multiple optional patents, and does not include any substitute patents, the patent pool does not have anti-competitive effect, but has pro-competitive effect, when the patent pool offers only the single package inclusive of all patents in the pool. The patent pool also enhances the total profit of patent holders and the total users' surplus.*

When the patent pool offer only the single package, users may not choice the package which they desire while the users can choice the package which they desire in absent of a patent pool. Even so, the social welfare is higher under a patent pool than in absent of a patent pool. This is because establishing a patent pool prevents high licensing fees set by individual patent holders, and decreases users' spending for using patents.

Similarly, we investigate whether the patent pool has anti-competitive effect or not, when the patent pool offers the multiple packages licensing. In the case, the users can choice the license package which they need, both under a patent pool and in absent of a patent pool. From the table 1, the necessary spending for using each combinations of patents is lower under a patent pool than in the absent of a pool. The necessary spending of users for using all patent 1, 2 and 3 under a patent pool is 0.862, which is lower than in absent of a patent pool, 1.167. The spending for using technology 1 and 2, or 1 and 3 under a patent pool is 0.667, which is lower than in absent of a patent pool, 0.783. Also in this case, a patent pool prevents high licensing fee set by individual patent holders, and decreases users' spending for using patents. Furthermore, from table 2, a patent pool enhances the total profit of patent holders and the total surplus of users. Therefore the following result is obtained:

Result 5. *If the patent pool is composed of basic patent and multiple optional patents, and does not include any substitute patents, the patent pool does not have anti-competitive effect, but has pro-competitive effect, when the patent pool offers the multiple packages licensing which users need. The patent pool also enhances the total profit of patent holders and the total users' surplus.*

Result 4 and 5 imply that the patent pool is pro-competitive and enhances both the total profit and users' surplus in either case. Therefore, the basic patents and the optional patents should be licensed through one administrator of a patent pool.

Next, we compare the case where the patent pool offers only the single package with the case where the patent pool offers the multiple packages, in order to get the implications for the multiple packages licensing. From table 2, we can find that the total users' surplus of the multiple packages licensing case is 0.254 which is higher than that of the single package licensing case, 0.152, while the pool's profit of the multiple packages licensing case is 0.550 which is lower than that of the single package licensing case, 0.667. The social welfare in the single package licensing case, 0.819, is higher than that in the multiple packages licensing case, 0.804. Summarized as follows:

Result 6. *In the multiple packages licensing case, the total surplus of users is higher than in the single package licensing case, but the patent pool's profit and the social welfare are lower.*

The social welfare in the single package licensing case is higher than in the multiple package licensing case, because the pool's profit is higher; the users' surplus is lower. The purpose of patent pools is promotion of developing the new technology and products; that is enhancing the users' surplus. Therefore, the multiple packages licensing case could be desirable, even if the social welfare is lower.

What is problem is whether a patent pool offers the multiple packages licensing which is desired by users or not. Does a patent pool have the incentive for offering the multiple packages licensing? Since the patent pool's profit is higher in the single package licensing case than the multiple packages licensing case. This implies that the patent pool offers only the single package inclusive of all patent in the pool for own profit, though there are the users who need not all of the patents in the pool but the subsets of the patents. The patent pool does not meet the diverse needs of users. It is often pointed out as "tie-in sale".

Result 7. *When the patent pool does not get the benefit except for the patent income profit, the patent pool does not offer the multiple packages which each user desires, voluntary. Only the single package inclusive of all the patents in the patent pool is offered.*

If the patent pool gets the benefits except for the patent income profit, the patent pool could offer the multiple packages license which each user desires. There are some possible benefits except for the patent income. We distinguish between patent holders and users, for simple analysis in our model. However, the patent pool members are licensees as well as the licensor. The patent pool members get the user's surplus using for the licenses which is licensed by the patent pool. That is, the patent pool could avoid lower users' surplus. Therefore, the patent pool has the incentive for offering the multiple packages licensing, if the patent pool members, themselves, want the multiple package licensing. When there is the encouragement or direction of any regulatory authority is also one way to urge a patent pool to offer the multiple packages licensing.

Finally, we need to discuss the incentive of the patent holders for establishing the patent pool which includes all patent 1, 2 and 3. By comparing the profits of each patent holder in individual licensing case with the pool's profit, we can get the following result:

Result 8. *When the patent pool does not get the benefit except for the patent income profit, the patent pool which includes all technology 1, 2 and 3 is established as the following the allocations of patent pool's profit to each patent holders. In the single package licensing case, the allocation to basic patent holder is higher than 28.0% of the patent pools profit, and the allocations to the holders of patent 2 and 3 are larger than 22.0%. In the multiple packages licensing case, the allocation to basic patent holder is higher than 34.0% of the patent pools profit, and the allocations to the holders of patent 2 and 3 are larger than 26.7%.*

This result shows the minimum allocations rate of patent pool's profit to each patent holder in order to establishing the patent pool, when the patent holders do not get the benefit except for the patent income profit. In many cases, the allocation rate of a patent pool's profit to each patent holder is $1/N^{th}$ (N is the number of patents in the patent pool) rule. That is, the patent holders receive the royalties of patent pool for their number of patents in the patent pool without the discussion and confliction of importance of each patent. Since the number of patents and their holders is 3 in this paper, the patent income profit which each patent holder can get is $1/3^{th}$ of the patent pool's profit. Then, all patent holders have the incentive for establishing the patent pool which offer only single package license. On the other hands, under the $1/3^{th}$ rule, the patent holder of basic technology could not be willing to establish the patent pool which offers the multiple package licenses; the patent holders of the optional technologies have the incentive for establishing. In the case, when the basic patent holders can get the large surplus by using the package licenses of patent pool, the basic patent holders has the incentive for establishing the patent pool. But when the basic patent holders cannot get the large surplus, the basic patent holder does not have the incentive. The way to give the

basic patent holders the incentive for participate the patent pool is increasing the allocation rate to the basic patent holder to more than 34%.

6. Conclusion

This paper discusses the social welfare implications for patent pools which administer many patents of patent holders and offer the license to licensees, from the view of an anti-competitive effect. The most important character of the paper is to consider the technical structure within the patent pool; the basic patent and the optional patent. There is a broad consensus that the patent pool which is composed of the basic patents enhances the social welfare. But it has been yet not determined whether the patent pool should include the optional patents which have diverse roles and aims, respectively. Our analysis obtains the result that the patent pool of the basic patent and the optional patents reduces the licensing fee and enhances the social welfare. This result provides the theoretical background for patent pools which is composed of the basic patents and the optional patents, such as the patent pools of DVD6C Agency and MPEG-LA etc. However, the result should discuss more carefully. Our paper does not consider the possibility that the patent pool inclusive of the optional patents prevents the competition with the other optional patents which are not included in the patent pool and are substitute for the optional patents in the patent pool.

We also focus on the multiple packages licensing which has not been the focus of any previous research on patent pools. The multiple packages licensing is important when the patent pool is composed of both the basic patents and the optional patents, since the aim of a patent pool depend on the optional patents which characterize the product. Our result is that the multiple packages licensing is difficult to be offered and only the single package licensing inclusive of all patents in the patent pool is offered, if the patent holders put the priority on the profit from licensing fee. This may explain that the actually-observed many patent pools offer only the single package licensing, though the patent pools include many optional patents. But the multiple packages licensing is desirable for licensees since the multiple packages licensing can provide only the patents which licensees need. Then the antitrust enforcement puts the priority on user' surplus and should promote the policy which makes patent pools offer the multiple packages licensing, since the aim of patent pools is to promote R&D and product development. Patent pools have the possibility to offer the multiple packages licensing, since the members of the patent pool actually get not only the profit from the patent pool but the profit from the use as licensees. The important thing is that patent pools offer the multiple packages licensing, if the members of the patent pool are going to enhance user's surplus in order to use patents in the patent pool and develop R&D and the product.

This paper builds up the specific model in order to analyze the special situations. Therefore the

implications of the analysis may be restrictive. But, it is important to describe the specific technical structures within the patents in the patent pool. By considering various technical structures and distributions of user's type, which we do not discuss in the paper, many results and rich implications could be brought about.

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Appendix 1:

Given the demand function (2), the patent pool maximize own profit $P(1,1,1)D^S$. When $1 \leq P(1,1,1) \leq 2$, the profit is

$$P(1,1,1)\left[\frac{\left\{2-P(1,1,1)\right\}^2}{2}\right]. \tag{A1}$$

Differentiating (A1) for $P(1,1,1)$,

$$-\left\{2-P(1,1,1)\right\}\left[\frac{3P(1,1,1)-2}{2}\right] < 0.$$

Then the profit is decreasing for $P(1,1,1)$, when $1 \leq P(1,1,1) \leq 2$, and the profit is $1/2$ when $P(1,1,1)=1$. Next, if $0 \leq P(1,1,1) \leq 1$, the profit is

$$P(1,1,1)\left[1-\frac{1}{2}\left\{P(1,1,1)\right\}^2\right]. \tag{A2}$$

The profit (A2) is maximized by the licensing fee satisfying the following F.O.C.

$$1-\frac{1}{2}\left\{P(1,1,1)\right\}^2 - P(1,1,1)^2 = 0. \tag{A3}$$

That is $P(1,1,1)=\sqrt{2/3}$ and the profit is $2/3$. As the result, we know the optimal licensing fee is $\sqrt{2/3}$.

Appendix 2:

If the licensing fees satisfy the inequality $P(1,1,1) > P(1,1,0) + P(1,0,1)$, the users who need all patents buy both the packages $(1,1,0,P(1,1,0))$ and $(1,0,1,P(1,0,1))$ rather than the package $(1,1,1,P(1,1,1))$. Given the licensing fees by the patent pool, the choices of user for the patent packages are the following manner:

・The users who does not buy any package satisfy $\begin{cases} a < P(1,1,0) \\ b < P(1,0,1) \\ b < -a + P(1,1,0) + P(1,0,1) \end{cases}$ (A4)

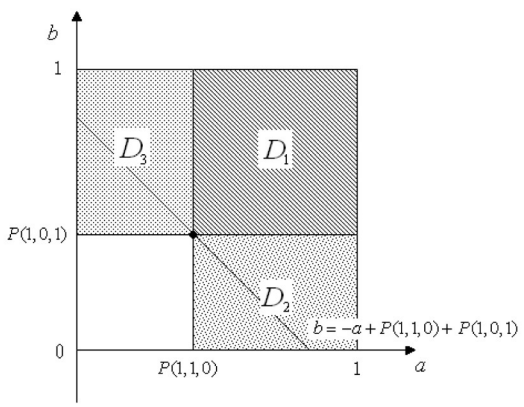
・$(1,1,0,P(1,1,0))$ is bought by the users who satisfy $\begin{cases} a \geq P(1,1,0) \\ b < P(1,0,1) \\ b \leq a + \{P(1,0,1) - P(1,1,0)\} \end{cases}$ (A5)

・$(1,0,1,P(1,0,1))$ is bought by the users who satisfy $\begin{cases} b \geq P(1,0,1) \\ a < P(1,1,0) \\ b > a + \{P(1,1,0) - P(1,0,1)\} \end{cases}$ (A6)

・Both $(1,1,0,P(1,1,0))$ and $(1,0,1,P(1,0,1))$ are bought by the users who satisfy

$$\begin{cases} a \geq P(1,1,0) \\ b \geq P(1,0,1) \\ b \geq -a + P(1,1,0) + P(1,0,1) \end{cases} \quad \text{(A7)}$$

Fig. 5



D^1 in Fig. 5 represents the area of users who buy the both package $(1,1,0,P(1,1,0))$ and $(1,0,1,P(1,0,1))$. D^2 and D^3 are the arias of users who buy the package $(1,1,0,P(1,1,0))$ and $(1,0,1,P(1,0,1))$, respectively. Calculating the aggregate demands for each package,

$$\begin{aligned} D_{110}^B &= \int_{P(1,1,0)}^{1}\int_{0}^{P(1,0,1)} 1\,db\,da + \int_{P(1,1,0)}^{1}\int_{P(1,0,1)}^{1} 1\,db\,da \\ &= P(1,0,1)\{1-P(1,1,0)\} + \{1-P(1,1,0)\}\{1-P(1,0,1)\} \end{aligned} \tag{A8}$$

$$\begin{aligned} D_{101}^B &= \int_{0}^{P(1,1,0)}\int_{P(1,0,1)}^{1} 1\,db\,da + \int_{P(1,1,0)}^{1}\int_{P(1,0,1)}^{1} 1\,db\,da \\ &= P(1,1,0)\{1-P(1,0,1)\} + \{1-P(1,1,0)\}\{1-P(1,0,1)\} \end{aligned} \tag{A9}$$

where D_{110}^B, D_{101}^B are the aggregate demands for $(1,1,0;\ P(1,1,0))$, $(1,0,1;\ P(1,0,1))$, respectively. Under the aggregate demand function of (A8) and (A9), the patent pool decides the licensing fees $P(1,1,0)$, $P(1,0,1)$ to maximize the following patent pool's profit.

$$\prod^B = \max P(1,1,0)\,D_{110}^B + P(1,0,1)D_{101}^B \tag{A10}$$

subjecting to $P(1,1,1) > P(1,1,0) + P(1,0,1)$ and licensing fee are non negative. Solving the problem (A10), numerically, we can obtain the solutions $P(1,1,0) = P(1,0,1) = 0.5$. The maximized profit is 0.5.